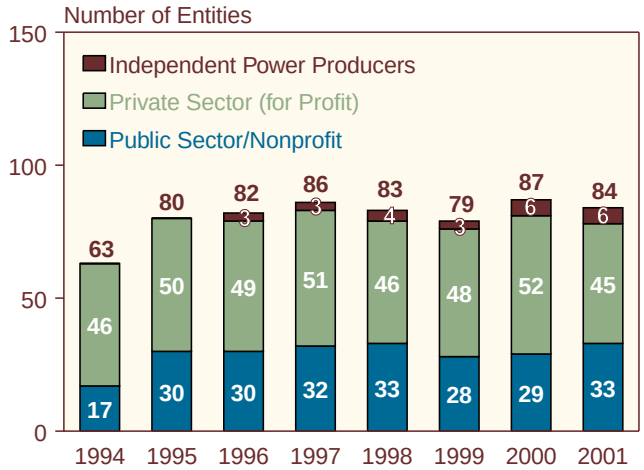
2. Reducing Emissions from Electric Power

Electric Power Industry

The electric power industry emitted approximately 2,243 million metric tons of carbon dioxide in 2001, 39 percent of total U.S. carbon dioxide emissions.[7] Carbon dioxide emissions result from the combustion of fossil fuels—coal, oil, and natural gas—during electricity generation. For example, coal, which accounted for 83 percent of electric power industry carbon dioxide emissions in 2001, is the primary energy source for U.S. electricity generation (providing 51 percent of total generation in 2001) and has the highest rate of carbon dioxide emissions per unit of energy used among fossil fuels.[8]

Since 1990, carbon dioxide emissions from the electric power industry have increased by 438 million metric tons or 23.7 percent, a trend that reflects U.S. economic growth (GDP grew by 37 percent between 1990 and 2001) and corresponding increases in fossil energy consumption in the electric power sector. In 2001, contrary to the upward movement in emissions since 1990, carbon dioxide emissions from the electric power industry decreased by 1.5 percent. Contributing to the decrease in emissions in 2001 was a 2.2-percent decrease in total electricity generation, a 2.6-percent decrease in coal-fired generation, and increases in the use of low-carbon fuels, including a 1.5-percent increase in natural-gas-fired generation and a 2-percent increase in nuclear generation.

Figure 4. Number of Electric Power Reporters Reporting on Form EIA-1605, by Entity Type, Data Years 1994-2001



Source: Energy Information Administration, Form EIA-1605.

Projects Reported

For the 2001 reporting year, a total of 84 electric power providers reported to the Voluntary Reporting Program on Form EIA-1605 (Figure 4). This is a decrease from the peak of 87 electric power providers reporting on the long form in 2000 but a 33-percent increase from the 63 reporters for the first reporting year, 1994. Since 1997, merger activity in the electric power industry as a result of deregulation has reduced the pool of electric utilities able to report to the Voluntary Reporting Program.[9]

Electric power providers make up 57 percent of the total 147 project-level reporters for data year 2001. Thirty-three of the electric power industry reporters were public sector or nonprofit organizations, including electric cooperatives, municipal utilities, and other public-sector entities such as the Tennessee Valley Authority (TVA). Forty-five entities were private-sector organizations, mostly investor-owned utilities (IOUs). Six independent power producers (IPPs) reported to the program for 2001, the same as the number reporting for 2000.

The 391 electric power projects reported for 2001 (Figure 5) represent a 10-percent decrease from the 2000 reporting year total of 434 but still a 106-percent increase from the 190 projects reported for 1994. Electric power projects were the most numerous project type reported to the Voluntary Reporting Program, accounting for 26 percent of all projects reported for 2001.

Electric power projects are reported in two categories: (1) carbon content reduction; and (2) increasing energy efficiency in generation, transmission, and distribution. Carbon content reduction projects include availability improvements, fuel switching, and increases in lower

[7]Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2001*, DOE/EIA-0573(2001) (Washington, DC, December 2002), web site www.eia.doe.gov/oiaf/1605/1605a.html.

[8]Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384(2001) (Washington, DC, November 2002), web site www.eia.doe.gov/emeu/aer/.

[9]There were 141 operating electric utilities in the United States in 2000, compared with 172 in 1992. See Energy Information Administration, *The Changing Structure of the Electric Power Inudstry 2000: An Update*, DOE/EIA-0562(00) (Washington, DC, October 2000), web site www.eia.doe.gov/cneaf/electricity/chg_stru_update/update2000.html.

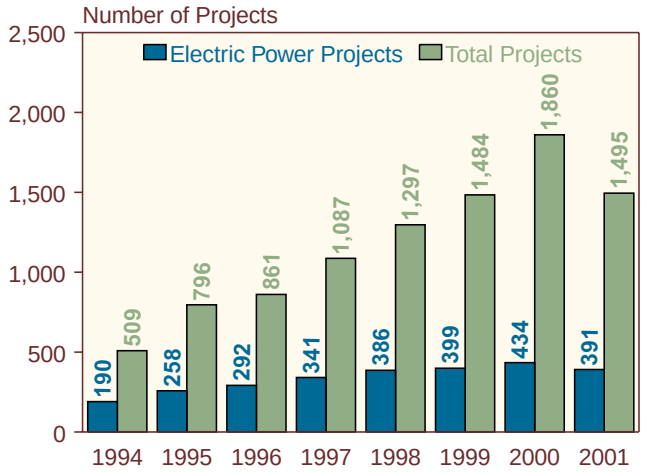
emitting capacity. Increased efficiency through generation, transmission, and distribution projects includes such activities as heat rate improvements, cogeneration and waste heat recovery, high-efficiency transformers, and reductions in line losses associated with electricity transmission and distribution. A total of 188 projects for increased energy efficiency in generation, transmission, and distribution were reported for 2001, and 225 carbon content reduction projects were reported.[10]

Reductions Reported

In 2001, total reported emission reductions from 391 electric power projects (Table 9) included 149.6 million metric tons carbon dioxide equivalent from direct sources and 17.6 million metric tons from indirect sources. The 225 projects in the category "reducing carbon content" reported emission reductions of 138.5 million metric tons carbon dioxide equivalent from direct sources and 15.2 million metric tons from indirect sources. The 188 projects included in the category "increasing energy efficiency in generation, transmission, and distribution" reported emission reductions of 14.3 million metric tons carbon dioxide equivalent from direct sources and 2.5 million metric tons from indirect sources.

Many of the largest projects reported to the Voluntary Reporting Program are electric power projects. In 2001, 31 electric power projects reported direct reductions of 1 million metric tons carbon dioxide equivalent or more, representing 79 percent of all the projects that reported direct emission reductions exceeding 1 million metric tons carbon dioxide equivalent. About three-quarters of the reported electric power projects were related to nuclear power.

Figure 5. Electric Power Projects and Total Projects Reported on Form EIA-1605, Data Years 1994-2001



Source: Energy Information Administration, Form EIA-1605.

Table 9. Number of Electric Power Projects and Emission Reductions Reported on Form EIA-1605 by Project Type and Reduction Type, Data Year 2001

Reduction Objective and Project Type	Number of Projects Reported	Emission Reductions Reported (Metric Tons Carbon Dioxide Equivalent)	
		Direct	Indirect
Reducing Carbon Content	**225**	**138,479,714**	**15,248,841**
Availability Improvements	38	76,187,246	9,136,880
Fuel Switching	49	5,136,203	270,409
Increases in Lower Emitting Capacity	105	60,287,612	6,678,455
Other Carbon Reductions	46	26,234,319	214,529
Increasing Energy Efficiency	**188**	**14,256,353**	**2,472,477**
Generation	*135*	*10,836,846*	*2,204,960*
Efficiency Improvements	117	8,240,615	1,084,096
Cogeneration and Waste Heat Recovery	18	2,596,231	1,120,865
Transmission and Distribution	*54*	*3,429,733*	*267,517*
High-Efficiency Transformers	26	1,381,868	225,971
Reconductoring	25	1,579,171	208,750
Distribution Voltage Upgrades	27	2,133,330	161,687
Other Transmission and Distribution	12	1,517,720	70,761
Total Electric Power Projects	**391**	**149,666,695**	**17,607,967**

Note: Project totals may not equal sum of components because some projects may be counted in more than one category.
Source: Energy Information Administration, Form EIA-1605.

[10]More than one project type may be assigned to a single project; therefore, the sums of the projects and reductions in many project type categories exceed the total numbers of projects and the total reductions reported.

Reducing the Carbon Content of Energy Sources

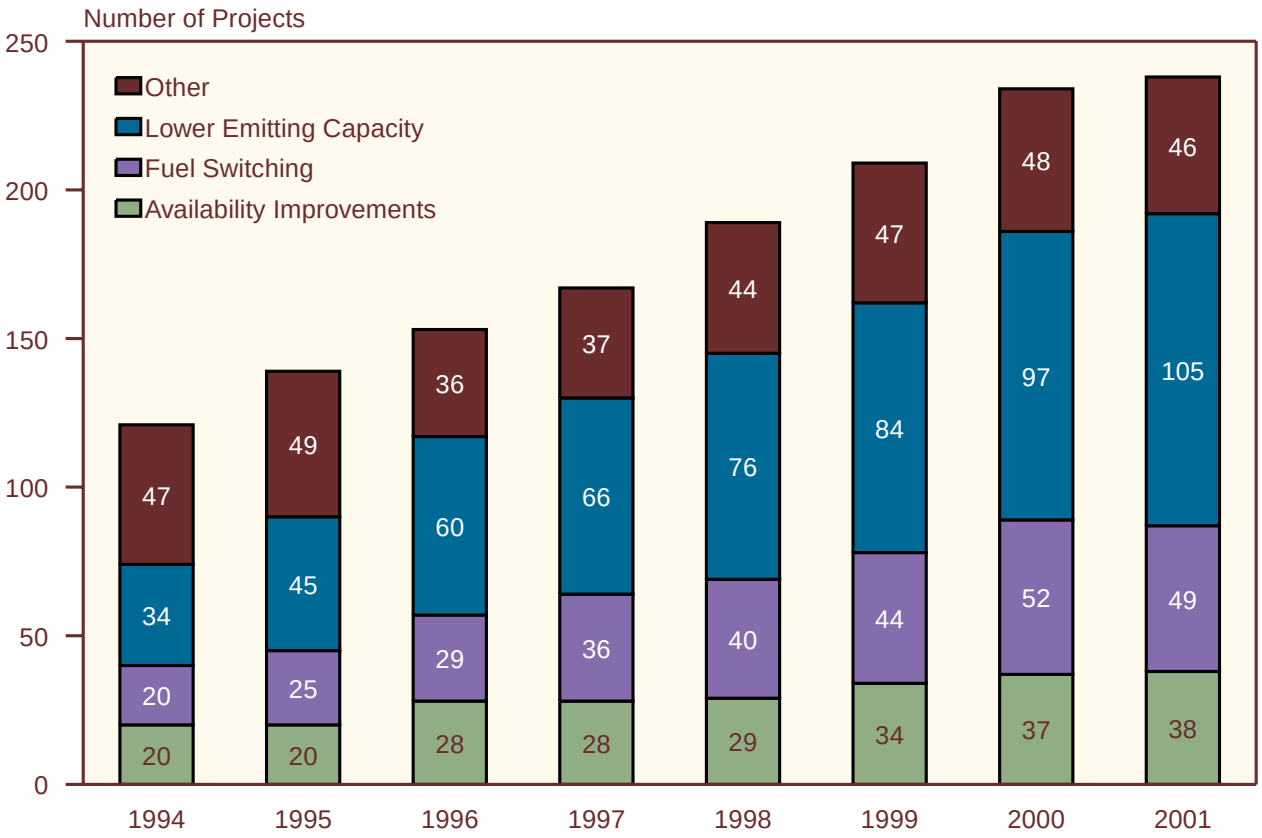
Projects involving fuel switching, power plant availability improvements, increases in low- or zero-emitting generation capacity, and other similar activities typically reduce the amount of carbon consumed to generate a unit of electricity. A total of 225 such projects were reported for 2001, including some of the largest projects reported to the Voluntary Reporting Program (Figure 6). The emission reductions reported for "carbon content reduction" electric power projects in 2001 totaled 138.5 million metric tons carbon dioxide equivalent from direct sources and 15.2 million metric tons from indirect sources. Some carbon content reduction projects are in fact "hybrids," combining efficiency improvements with measures such as availability improvements or increases in low-emitting capacity (see box on page 24).

Availability Improvements

By increasing generation from lower emitting power plants, availability improvement projects provide a commensurate reduction in the amount of generation supplied by higher emitting plants. The number of availability improvement projects reported for 2001 was 38—1 more than the 37 reported for 2000 and 18 more than the 20 reported for 1994. Availability improvement projects accounted for reported emission reductions in 2001 totaling 76.2 million metric tons carbon dioxide equivalent from direct sources and 9.1 million metric tons from indirect sources. As for previous reporting years, availability improvement projects, especially those undertaken at nuclear facilities, produced some of the largest reported reductions in carbon dioxide emissions. Of the 38 availability improvement projects reported, more than one-half involved nuclear power plants. Mainly through significant advances in operating, maintenance, and refueling procedures, capacity factors at nuclear plants were increased, displacing some fossil-fuel-based power generation.

Because nuclear power plants are invariably large baseload facilities, even a fairly small improvement in plant availability can lead to a sizable reduction in fossil fuel consumption. For example, Dominion Generation reported the project, "Increased Nuclear Generation at Surry Power Station," involving an increase in the total annual electrical output of the Surry Power Station for 2001 above the station's 1987-1990 baseline output. The increase, which resulted from an increase in the station's

Figure 6. Electric Power Projects Reported on Form EIA-1605 Reducing the Carbon Content of Energy Sources, by Project Type, Data Years 1994-2001



Note: The sum of projects in many project categories exceeds the total number of projects reported, because more than one project type may be assigned to a single project.

Source: Energy Information Administration, Form EIA-1605.

availability, meant that less electricity was generated at Dominion's coal-fired generating facilities. The net result was a reduction in Dominion's annual carbon dioxide emissions below what they would have been had Surry's output not increased. For 2001, Dominion reported a change of 6,364 gigawatthours of generation from bituminous coal to nuclear power for this project, directly reducing carbon dioxide emissions by 5.9 million metric tons.

Fuel Switching

Forty-nine fuel-switching projects were reported for 2001, 3 less than the 52 reported for 2000 and 29 more than the 20 reported for 1994. Switching from coal or oil to natural gas lowers carbon dioxide emissions because of the lower carbon content of natural gas relative to other fossil fuels. For example, switching from bituminous coal to natural gas can reduce carbon dioxide emissions per unit of energy consumed by approximately 43 percent. Although other reported actions, such as switching from oil to gas, may not lead to reductions of the same magnitude, they also reduce greenhouse gas emissions. The fuel-switching projects reported for 2001 accounted for emission reductions totaling 5.1 million metric tons carbon dioxide equivalent from direct sources and 0.3 million metric tons from indirect sources.

An example of a fuel-switching project is a phased gas expansion project to increase the use of natural gas as a fuel, reported by Florida Power & Light (FPL). FPL implemented steps in the early 1990s to significantly increase the availability of competitively priced natural gas supplies for future generating units. This was done at a time when FPL's integrated resource plan and fuel diversity strategies called for the construction of pulverized coal units. The expansion of FPL's natural gas supplies allowed the utility to construct two new state-of-the-art high-efficiency combustion turbine combined-cycle plants (the Lauderdale Repowering Project and the Martin Combined Cycle Project) in lieu of two 720-megawatt pulverized coal units originally considered. In addition, the innovative, first-of-a-kind repowering of the Lauderdale steam-electric plant allowed for the retirement of two old, inefficient 137-megawatt oil/gas utility boilers. In 2001 the project reportedly displaced 97 trillion Btu of residual fuel for an equal amount of natural gas at Ft. Lauderdale units 4 and 5 and Martin units 3 and 4, reducing carbon dioxide emissions by 2.6 million metric tons.

Increases in Lower Emitting Capacity

Projects involving the construction of new, lower emitting power plants or increases in the capacity of existing lower emitting plants were among the most numerous electricity supply projects reported. A total of 105 such projects were reported for 2001, up from 97 reported for 2000 and 34 for 1994. Most involved increases in nuclear (23 projects), hydropower (19 projects), photovoltaic (16 projects), and wind capacity (36 projects) and other system efficiency improvements—increasing the output of power sources with essentially no greenhouse gas emissions. Emission reductions reported for increases in

Electricity Supply Carbon Reduction Projects: Definitions and Terminology

The combustion of fossil fuels to produce heat for electricity generation causes greenhouse gas emissions. In addition to substantial releases of carbon dioxide, fossil fuel combustion also emits small quantities of methane and nitrous oxide. Carbon content reduction projects typically reduce greenhouse gas emissions by replacing higher emitting fuels (such as coal) with lower emitting fuels (such as natural gas) or non-emitting energy sources (such as nuclear power or renewables). Projects that reduce the carbon content of electricity supply include the following.

Availability Improvements. By reducing the frequency and length of planned and unplanned power plant outages, availability improvement projects can result in increased use of the affected plant. This is particularly true if the plant is a *baseload* plant (i.e., a plant that is generally used on an around-the-clock basis except during plant outages), but it may hold true for other types of plants as well. If the resulting increase in generation from the affected plant displaces generation that otherwise would have been produced by a higher emitting plant, emission reductions will result. Power plant utilization is measured by the plant's *capacity factor*, defined as the ratio of the average load on the plant over a given period to its total capacity. For example, if a 200-megawatt plant operates (on average) at 75 percent of its rated capacity (i.e., at a load of 150 megawatts) over a period of a year, the plant's capacity factor is 75 percent for that year.

Fuel Switching. The amount of carbon contained in fossil fuels and released in the form of carbon dioxide during combustion varies, depending on the type of fuel. Thus, carbon dioxide emissions from a power plant can be reduced by switching from a higher emitting fuel (such as coal) to a lower emitting fuel (such as natural gas).

Increases in Lower Emitting Capacity. By increasing the capacity of an existing lower emitting or non-emitting plant (e.g., a hydroelectric plant), or by constructing new generating capacity (e.g., wind turbines), a utility can reduce or avoid reliance on higher emitting plants. The result will be a reduction in greenhouse gas emissions from the displaced plants.

low-emitting capacity projects in 2001 totaled 60.3 million metric tons carbon dioxide equivalent from direct sources and 6.7 million metric tons from indirect sources.

Exelon Corporation began the Chicago Public School Solar Partnership in August 2000. The partnership started with Reilly Public School, and four schools are now participating. Each school has a 10.8-kilowatt solar array. Based on the assumption that 1 kilowatt produces approximately 1,487 kilowatthours annually in the Chicago area, the four systems collectively produced an estimated 64,238 kilowatthours in 2001, indirectly reducing carbon dioxide emissions by 47 metric tons, nitrous oxide emissions by 1.65 pounds, and methane emissions by 0.79 pounds. Although the reductions are small in comparison with other projects, the benefits of the partnership are to raise awareness and educate the public about alternative energy resources. The partnership conducts projects, seminars, demonstrations, and workshops. The benefits for the Chicago Public Schools are twofold: (1) on-site stationing of large numbers of photovoltaic systems whose costs are heavily, or sometimes completely, leveraged by outside parties; and (2) installation of energy systems that require minimal maintenance and can be worth thousands of dollars in annual electricity cost avoidance.

Other Carbon Reduction Projects

Forty-six "other carbon reduction" projects were reported for 2001, 2 less than reported for 2000 and 1 less than reported for 1994. This category of "other" projects includes projects that decrease high-emitting capacity, make dispatching changes only, or increase low- or zero-emitting capacity. In 2001, 26 projects used low- or zero-emitting power purchases to reduce emissions. This category was added to the Voluntary Reporting Program in 1999 to classify electric power producer/supplier purchases of power from low- or zero-emitting generation sources for resale, replacing generation or purchases of power from more carbon-intensive generation sources. Another 3 projects reported for 2001 involved decreases in higher emitting capacity, and 3 involved changes in the dispatching of power plants. Changes in dispatch order can reduce carbon dioxide emissions if lower emitting plants are used more frequently. For 2001, reported emission reductions from "other carbon reduction" projects totaled 26.2 million metric tons carbon dioxide equivalent from direct sources. An emissions increase of 0.2 million metric tons carbon dioxide equivalent was reported from indirect sources.

An example of a "dispatching changes only" project is the "Merger Dispatch Savings" project reported by Cinergy. Emission reductions were achieved through the economic dispatch of Cinergy's generating facilities. Before the merger of the Cincinnati Gas & Electric Company and PSI Energy, the same generating facilities were dispatched according to the demands of each operating company. After the merger, the units from both operating companies were operated and dispatched as if a single company owned them. This method of operation and economic dispatch is estimated to provide a 1-percent efficiency gain in the operation of the system. The efficiency gain is realized because the more recently built generating units are the most efficient units, and these are the first dispatched to meet customer demands for electricity. Therefore, the most efficient generating units are operating more than the older, less efficient units. In 2001, Cinergy reported a decrease in energy consumption of 253,374 short tons of bituminous coal and direct reductions of 566,757 metric tons of carbon dioxide emissions.

In another project reported for 2001, We Energies' Energy for Tomorrow™ renewable energy program allows customers to choose to have some or all of their energy come from renewable-based generation. The program began in June 1996 as a combination of underutilized wood waste and hydroelectric capacity from a neighboring utility. In 1997, local area hydropower suppliers were added. In 1999, We Energies installed two wind turbines to provide generating capacity for the program. Landfill gas generation from Waste Management of Wisconsin, Inc., was also added and is reported to the Voluntary Reporting Program. In 2001, landfill gas was used in the project to generate 24,905 megawatthours of electricity. Program participants' use of energy from renewable-based generation offsets generation at coal-fired facilities, which reduces emissions. We Energies reported on 25 percent of this project and filed it as a zero/low-emitting power purchase project and an increase in low-emitting capacity project. In 2001, We Energies reported changes in energy consumption that included a decrease of 8,456 megawatthours of electricity generated from coal as the result of increases of 2,500 megawatthours of generation from hydropower and 5,956 megawatthours from wind energy, directly reducing carbon dioxide emissions by 8,958 metric tons.

Increasing Energy Efficiency in Electricity Production and Distribution

Projects involving improvements in the efficiency of electricity generation, transmission, and distribution were more numerous than the other electric power projects reported for 2001 but produced smaller emission reductions on average. Efficiency improvement tends to be an ongoing effort by electricity suppliers, yielding a continuous stream of small, incremental improvements rather than one-time dramatic increases in efficiency. For example, heat rate improvement projects often are undertaken in response to normal plant deterioration. As power plants age, efficiency tends to erode gradually. Operators seek to maintain heat rates by replacing or refurbishing old, worn-out equipment. Similarly,

new energy-efficient transformers are often installed gradually over a period of years, as old transformers fail.

A total of 188 "increasing energy efficiency" projects were reported for 2001, including some hybrid projects that combined efficiency improvements with measures such as availability improvements. The efficiency improvement projects fall into two main categories: (1) generation, involving efficiency improvements in the conversion of fossil fuels and other energy sources into electricity; and (2) transmission and distribution, involving improvements in the delivery of electricity from the power plant to the end user (see box on page 28).

Generation Projects

Efficiency Improvements. Improvements in generating efficiency were the most numerous type of efficiency project reported for 2001. A total of 117 such projects were undertaken in 2001. Heat rate improvements at coal-fired power plants are a commonly reported means of increasing efficiency and reducing carbon dioxide emissions. There are numerous opportunities for improving efficiency at existing power plants, but the efficiency gains, and hence reductions in fuel consumption and emissions, are limited by technology and tend to be small. Emission reductions reported for generation efficiency improvement projects in 2001 totaled 8.2 million metric tons carbon dioxide equivalent from direct sources and 1.1 million metric tons from indirect sources.

FirstEnergy Corporation reported heat rate efficiency improvements on the Ohio Edison System that were accomplished through: (1) shutdown of less efficient coal-fired boilers, (2) installation of enhanced boiler controls, and (3) turbine modifications. With the shutdown of less efficient boilers, it is expected that the remaining boilers in the Ohio Edison System will meet the demand for electricity while requiring less fuel and, therefore, emitting less carbon dioxide. In 2001, this project reported a reduction of 8.6 trillion Btu in consumption of bituminous coal, resulting in direct reductions of 807,037 metric tons of carbon dioxide emissions. The carbon dioxide emission reduction estimates were based on existing operation data, such as heat content of fuel consumed (Btu) and total electricity produced (kilowatthours), which were used to derive the heat rate (Btu per kilowatthour). The reference case heat rate was the average of the baseline period from 1987 to 1990. Reduction in the heat rate is the difference between the reference case heat rate and the individual heat rate for 2001. The energy saved (Btu) due to heat rate improvement is the product of the total electricity produced and the improved heat differential for each of the subsequent years.

Entergy reported on general generator improvements with the project, "Louisiana Station 1 Repowering and Unit Upgrade." In late 1997, a major expansion at the Louisiana Station 1 was completed. The main elements of the expansion were the installation of a 150-megawatt gas combustion turbine with associated heat recovery steam generator, refurbishment of three boilers, and an upgrade of the existing gas turbine. The new combustion turbine increased thermal input by 1,473 million Btu per hour, but the reduction in operation of three boilers decreased thermal input by 909 million Btu per hour, and maintaining another boiler on cold standby reduced thermal input by 630 million Btu per hour; thus, the expansion resulted in a decrease in heat input of 66 million Btu per hour. In 2001, this project reported a reduction of 338,646 million Btu in consumption of natural gas, resulting in direct a reduction of 17,819 metric tons of carbon dioxide emissions.

Cogeneration and Waste Heat Recovery. A total of 18 cogeneration and waste heat recovery projects were reported for 2001, as compared with 4 projects reported for 1994. Emission reductions reported for cogeneration and waste heat recovery projects in 2000 were, on average, larger than those reported for any of the other types of efficiency improvement projects but less than the average for carbon content reduction projects. Industrial partners in the cogeneration projects reported for 2001 include a greenhouse, steel mills, and a heating plant in the Czech Republic. Reported end uses of the thermal energy include electricity generation, process heat applications, space heating and cooling, and cooking. The emission reductions reported for cogeneration and waste heat recovery projects in 2001 totaled 2.6 million metric tons carbon dioxide equivalent from direct sources and 1.1 million metric tons from indirect sources.

Minnesota Power reported on a new cogeneration project that began in June 2001. Minnesota Power installed, and is the operator of, Cloquet Energy Center Turbine Generator 5. The new unit, with approximately 23 megawatts net capacity, was placed in a process steam line where steam previously had been throttled to lower pressure for process use. Consequently, the electricity produced had an overall 83-percent process efficiency from steam produced from boilers fueled by 50 percent natural gas and 50 percent mill process wood waste (biomass). It was estimated that the cogeneration application heat rate was 4,112 Btu per net kilowatthour of electricity generation, displacing conventional generation fired by subbituminous coal. Minnesota Power owns and operates the turbine, providing payment to Sappi Limited (owner of the Cloquet paper mill) for steam when Minnesota Power produces electricity for the grid. In 2001, this project reported direct emission reductions of 55,134 metric tons carbon dioxide.

PEI Power reported a cogeneration project in which waste process heat was used for electricity generation,

industrial process heat, and heating, cooling, and ventilation. The PEI Power boiler is capable of firing landfill gas and pipeline natural gas. The unit is operated to burn landfill gas first and then use natural gas as a supplement. The boiler produces steam that is put through a steam turbine to produce electricity. After the steam goes through the three stages, the end product is then used to produce hot water for an adjacent greenhouse. Also, steam comes off the first extraction and goes to a plastic manufacturer for process use. In 2001, this project reported energy consumption of 760.1 billion Btu from landfill gas and 88.6 billion Btu from natural gas to generate 6.4 million kilowatthours of electricity, with corresponding direct emission reductions of 628 metric tons carbon dioxide and indirect emission reductions of 36,169 metric tons carbon dioxide.

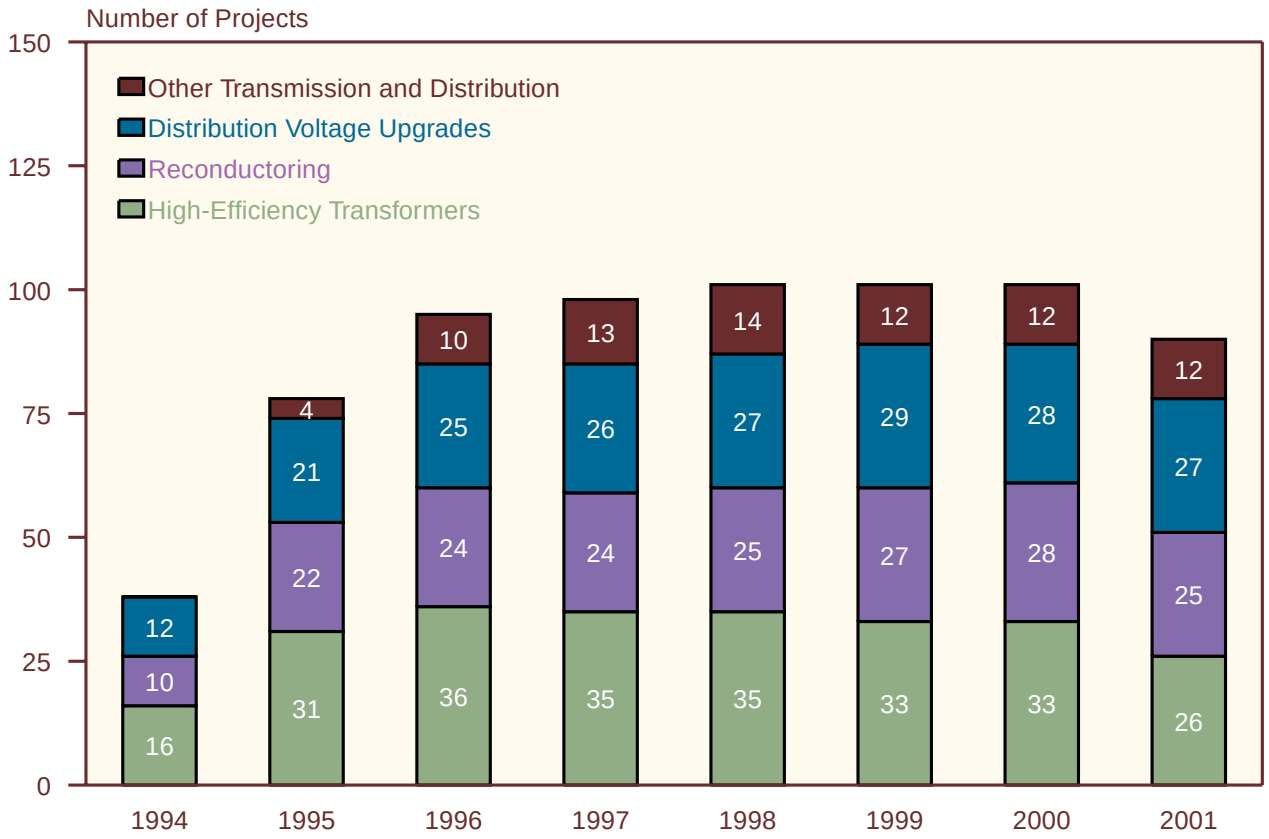
Transmission and Distribution Projects

Transmission and distribution projects, although not as numerous as generation projects, were nonetheless reported in significant numbers. For 2001, 54 transmission and distribution projects were reported. Unlike generation projects, which typically have discrete start and completion dates, efforts such as upgrading conductors and replacing transformers are ongoing activities by electric power producers. Consequently, most of the transmission and distribution efficiency improvements reported for 2001 were reported as continuations of long-standing projects rather than as new projects.

In terms of average emission reductions, transmission and distribution projects typically are somewhat smaller than generation projects. There are numerous opportunities for improving efficiencies in the delivery of electricity, but the magnitude of the efficiency gains that can be realized is limited.

For 2001, the most frequently reported types of transmission and distribution projects (Figure 7) were high-efficiency transformers (including improved silicon steel and amorphous core transformers); reconductoring (replacing existing conductors with large-diameter conductors to reduce line losses); and distribution voltage upgrades (increasing the voltage at which the various segments of the system operate to reduce line losses). The other transmission and distribution project category includes projects that involve more than one type of activity, as well as such activities as transmission line improvements and capacitor installations. A total of 26 high-efficiency transformer projects were reported

Figure 7. Reported Transmission and Distribution Projects Reported on Form EIA-1605 by Type, Data Years 1994-2001



Note: The sum of projects in many project categories exceeds the total number of projects reported, because more than one project type may be assigned to a single project.

Source: Energy Information Administration, Form EIA-1605.

for 2001, 7 less than the 33 reported for 2000 and 10 more than the 16 reported for 1994. Many of the reported projects were "hybrid" projects, combining high-efficiency transformer installation with one or more other transmission and distribution activities (e.g., reconductoring).

Another 25 projects involving reconductoring and 27 projects involving distribution voltage upgrades (again, often in combination with other activities) were reported for 2001, both lower than the numbers reported in the same categories for 2000. The reporters classified

Efficiency Projects: Definitions and Terminology

Generation Projects

It is neither theoretically nor practically possible to convert all the thermal or other energy produced in, or consumed by, a power plant into electrical energy. In fact, much of the energy is lost rather than converted. Typically, U.S. steam-electric generating plants operate at efficiencies of about 33 percent, meaning that two-thirds of the thermal energy produced is lost. Some more advanced power plants have higher efficiencies, but even new combined-cycle plants (in which the waste heat from a gas turbine is recovered to produce steam to drive a turbine) typically have efficiencies of only 50 to 60 percent. Generation projects seek to improve power plant efficiencies either by reducing the amount of energy lost during the conversion process or by recovering the lost energy for subsequent application.

Efficiency Improvements. By increasing the efficiency of the generation process, efficiency improvement projects at fossil-fuel-fired power plants reduce the plants' *heat rate*, defined as the amount of fossil energy (measured in Btu) needed to produce each kilowatthour of electricity. The result is a reduction in the amount of fuel that must be burned to meet generation requirements, and hence a reduction in carbon dioxide (and other greenhouse gas) emissions. Efficiency improvements at nonfossil (e.g., hydroelectric) power plants can also reduce greenhouse gas emissions. Emission reductions occur if the efficiency improvement leads to an increase in the amount of electricity generated by the affected plant, with a consequent reduction in the amount of electricity that must be generated by other (fossil fuel) plants to meet demand.

Cogeneration. Only a portion of the heat generated during the combustion of fossil fuels can be converted into electrical energy; the remainder is generally lost. Cogeneration involves the recovery of thermal energy for use in subsequent applications. Cogeneration facilities typically employ either topping or bottoming cycles. In a *topping cycle*, thermal energy is first used to produce electricity and then recovered for subsequent applications. Topping cycles are widely used in industry as well as utility power plants that sell electricity and steam to customers. In a *bottoming cycle*, the thermal energy is first used to provide process heat, from which waste heat is subsequently recovered to generate electricity. Bottoming cycle applications are less common, usually associated with high-temperature industrial processes. Because cogeneration involves the recovery and use of thermal energy that would otherwise be wasted, it reduces the amount of fossil fuel that must be burned to meet electrical and thermal energy requirements, hence reducing greenhouse gas emissions.

Transmission and Distribution Projects

The purpose of the electricity transmission and distribution system is to deliver electrical energy from the power plant to the end user. Resistance to the flow of electrical current in cables, transformers, and other components of the transmission and distribution system causes a portion of the energy (typically about 7 percent) to be lost in the form of heat. Improving the efficiency of the various system components can decrease such line losses, reducing the amount of generation required to meet end-use demand and, thus, power plant fossil fuel consumption and greenhouse gas emissions.

High-Efficiency Transformers. Transformers, used to change the voltage between different segments of the transmission and distribution system, are a source of system losses. Transformer losses occur as a result of impedance to the flow of current in the transformer windings and because of hysteresis and eddy currents in the steel core of the transformer. When existing transformers are replaced with high-efficiency transformers (including improved silicon steel transformers and amorphous core transformers), losses are reduced.

Reconductoring. Like transformers, conductors (including feeders and transmission lines) are a source of transmission and distribution system losses. In general, the smaller the diameter of the conductor, the greater its resistance to the flow of electric current and the greater the consequent line losses due to heating. Reconductoring involves the replacement of existing conductors with larger diameter conductors.

Distribution Voltage Upgrades. Line losses are dependent, in part, on the voltage at which the various segments of the transmission and distribution system operate. Upgrading the voltage of any segment can reduce line losses.

12 projects as "general" or "other" transmission and distribution, the same number as reported for 2000. Emission reductions reported for transmission and distribution projects in 2001 totaled 3.4 million metric tons carbon dioxide equivalent from direct sources and 0.3 million metric tons from indirect sources.

The Los Angeles Department of Water and Power (LADWP) reported a project to install energy-efficient transformers. A total of 1,857 transformers—both overhead and pad-mounted, with various loads and voltages—were in use as of May 2002. Total energy saving was calculated by multiplying energy saving per transformer by the quantity of each type of transformer. The average total energy saving was then multiplied by the total hours of operation per year to arrive at the annual energy saving. Carbon dioxide emission reductions were calculated by multiplying the annual energy saving by the LADWP's fossil-fueled power plant emission factor. In 2001, this project reported a decrease in electricity consumption of 1.4 gigawatthours and direct emission reductions of 1,064 metric tons carbon dioxide.

Kansas City Power & Light Company reported the installation of new transmission lines, reconductoring of old lines to improve efficiency, and a power flow management system. In 2001, this project reported a decrease in electricity consumption of 31,105 megawatthours and direct emission reductions of 34,398 metric tons carbon dioxide.

Seattle City Light reported a project on distribution voltage upgrades. The energy savings were derived from replacing 4-kilovolt unit substations and their attendant losses with the smaller losses of a 26-kilovolt system. Eliminating 4-kilovolt distribution feeders decreased distribution feeder losses, and installing larger capacity 26-kilovolt transformers reduced distribution (pole-top) transformer losses. Since 1992, this project has converted 32 substations and each 4-kilovolt substation eliminated represents a total savings of 5.5 kilowatthours per substation conversion. In 2001, the project reported a decrease in electricity generation of 1,542 megawatthours and indirect emission reductions of 605 metric tons carbon dioxide.